Fermilab

$\bar{p}$ Note #367

TeV I Electrodes Formed Microwave Assembly Pickup Cooling Evaluation

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12/14/83

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TEV I Electrodes
Formed Microwave Assembly
Pickup Cooling Evaluation

Summary

Cooling of the "formed" version of the TEV I Electrode microwave assembly when operated as a pickup has been evaluated with a series of tests incorporating engineering models of the microwave assembly. The major objective of the evaluation was to determine the operating temperatures of the resistor (electrical noise) and the combiner board (outgassing). A nominal resistor power of 0 watts and LN_2 cooling were assumed.

The evaluation consisted of the following elements:

I. Single Pair LN_2 Tests
Details are per the attached memorandum "Single Pair LN_2 Tests", MF/RN/DV, 9/14/83. Summary is as follows:

A. Objective
The test objective was to conduct a preliminary evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a pickup with LN_2 cooling.

B. Test Arrangement
The test article corresponds to a single cavity pair slice of a 1-2 GHz formed microwave array. The components have the geometry of the 1-2 GHz microwave array production design. Differences from the production design are as follow:

1. The loop was simulated with a copper wire whose cross section approximated that of a LBL model loop design.

2. The circuit board was unetched.

3. A circuit board connector was not employed.

4. Only the upper half of the test article had a simulated loop and circuit board.

The test article was contained in and supported from a shield. The shield consisted of a copper cylindrical section, having coolant flow loop, with removable circular end sections.

The test article and shield assembly were installed in a vacuum tank.

II. Conclusions

A. The resistor temperature, as inferred from the cavity temperature, varies with the nature of the shield and its cooling. Cavity wall temperatures range from 91K for a totally cooled shield with good array-shield thermal contact to 156K with an uncooled shield with a spring thermal short to the sideplane. In all cases, the cavity temperature exceeded the required resistor operating temperature of 90K; i.e., -300°F.

B. All pickup cooling configurations evaluated should satisfy the requirement for circuit board cooling having a circuit board temperature of less than 250 K; i.e., -10°F. The worst case; i.e., highest, board temperature measured was 205K; i.e., -90°F.

III. Single Pair Pickup Tests

Details are per the attached memorandum "Single Pair Pickup Tests", MF/RN/DV, 11/27/83. Summary is as follows:

A. Objective
The test objective was to continue the evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a pickup with liquid nitrogen cooling. Of specific interest was the determination of the steady state resistor temperature for an array located in a full, liquid nitrogen cooled shield.

B. Test Arrangement
The test arrangement is per the previous pickup cooling evaluation with the following modifications:

1. An actual instrumented loop assembly was installed.
2. An etched combiner board was installed.
3. An instrumented combiner board connector was installed.
4. Good array-shield thermal contact was made.
5. The shield end orientations were reversed.
6. Thermocouple were changed to Type T 28 gauge and were monitored with a commercial data logger.

C. Conclusions

1. Steady state resistor operating temperatures in the - 300°F; i.e., 90 K, region should be obtainable where the resistor temperature runs approximately 15°F; i.e., 9 K, above that of the array coolant.
2. As per attached test.

Attachments

MF/RN/DV
9/14/83

TEV I Electrodes
Formed Microwave Assembly
Single Pair LN_2 Tests

I. Objective

The test objective was to conduct a preliminary evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a pickup with LN_2 cooling.

II. Test Arrangement

The test arrangement is as shown by Figure 1.

A. Test Article

The test article corresponds to a single cavity pair slice of a 1-2 GHz formed microwave array. The components have the geometry of the 1-2 GHz microwave array production design. The test article is as shown by Figure 2a.

Differences from the production design are as follow:

1. The loop was simulated with a copper wire whose cross section approximated that of the latest LBL model loop design. The wire was 3 3/4 inches long and had a diameter of 0.050 inches. The simulated loop is as shown by Figure 2b.

2. The circuit board was unetched.

3. A circuit board connector was not employed.

4. Only the upper half of the test article had a simulated loop and circuit board.

B. Shield

The test article was contained in and supported from a shield. The shield consisted of a 1/16 inch thick copper cylindrical section, having a coolant flow loop, with removable circular end sections. The end sections consisted, from the exterior to the interior, of a 1/16 inch thick G10 disc, 25 layers of multilayer insulation, of a 1/16 inch thick copper disc. The copper disc was in thermal contact with the cylindrical portion of the shield. The test article was mounted to the shield by threaded fasteners on the horizontal centerline of the assembly. The test article-shield relation is as shown by Figure 2c.

C. Vacuum Tank

The test article and shield assembly were installed in a vacuum tank. The unit was supported by G10 rods cantilevered from the tank flange. The arrangement is as shown by Figure 2d.

The tank was evacuated with a turbomolecular pump.

D. Instrumentation

The test article and shield were instrumented with Type J 20 gauge thermocouple wire. The junctions were made by welding and were fastened to the test article by mechanical clamping. Thermocouple locations are as given by Table 1.

The thermocouples were manually monitored with a commerical readout having a built in reference junction. The calibration of the system was checked at the water boiling, ice melting and LN_2 boiling points.

The array coolant and shield coolant flow rates were monitored with rotameter type flowmeters. The discharge flow was measured after warming to ambient temperature with a gas to water heat exchanger.

The tank vacuum was monitored with a thermocouple type vacuum gauge.

III. Procedure

A. Variables

The test plan was developed to evaluate several factors that could affect the operating temperatures of the resistor (electrical noise) and the circuit board (outgassing). The plan is as outlined by Table 2.

B. Sequence

The vacuum tank was evacuated to the minimum pressure obtainable with the pumping system.

Baseline temperature measurements were made with the test article and ambient temperature and with no coolant flow.

LN_2 coolant flow was initiated as per the test plan and temperature data was taken at regular intervals.

Data was taken until quasi steady state temperatures were reached.

IV. Results

A typical transient cooling curve is as shown by Figure 5.

The quasi steady state results are as given by Table 3. Typical array and shield coolant rates were 200 SCFH.

V. Discussion

A. Run 1 - Operation in the LBL configuration; ie, with a full shield and with good thermal contact between the shield and the array, results in a low; ie, less than -250°F, and essentially uniform temperature distribution over the array. The effects of circuit board cooling through the loop is evidenced by the board being colder than the directly adjacent side plane.

B. Run 2 - Operation without a shield results in a nonuniform temperature distribution across the array. Circuit board cooling through the loop is more apparent for this case.

C. Run 3 - Replacement of the array to shield brass mounting hardware with G10 hardware reduced the heat influx from the uncooled shield. The change had little effect on the circuit board temperature as compared to Run 2.

D. Run 4 - Operation with a local shield reduced the sideplane and, correspondingly, the circuit board temperatures. The effect is, as expected, localized as evidenced by the essential constancy of the other array temperatures.

E. Run 5 - Operation with a spring contact thermal short was ineffective as can be seen upon comparision with Run 3.

F. Run 6 - Operation with a solder contact thermal short was very effective when the circuit board temperature is considered to be the principle criteria.

G. Run 7 - Operation with a poor thermal connection between the array and the shield was not significantly different than that with a good thermal connection. Thus the shield and array could be connected at fewer points along their lengths without significantly affecting the performance of the assembly.

H. Run 8 - Removal of the simulated loop, as expected, reduced the heat transfer from the circuit board. The board temperature remains below that of the adjacent sideplane, most likely due to cooling of the board through its edges coupled with being in an area of reduced radiant heat transfer.

VI. Conclusions

All LN_2 pickup cooling configurations evaluated by the series should satisfy the presently stated requirement for circuit board cooling having a circuit board temperature of less than 250 K; ie, -10°F.[1] The worst; ie, highest, case board temperature measured was 205K; ie, -90°F, which corresponded to Run 5.

Note
1 J. Marriner, Private communication, July 1983.

TABLE 1
THERMOCOUPLE LOCATIONS

TC NO.	LOCATION
T1	LN_2 Supply Tube
T2	Cavity wall near resistor assembly
T3	Side plane at geometric center
T4	Circuit board at geometric center
T5	Beam tube at halfway point between cavity edge and beam tube edge
T6	Beam tube side at horizontal centerline
T7	Cylindrical shield

TABLE 2
TEST PLAN OUTLINE

TEST Run NO.	PURPOSE	ARRAY COOLED	SHIELD COOLED	ARRAY-SHIELD THERMAL CONNECTION	COOLING CHANGES
1	To evaluate performance in the LBL configuration; ie, total cooled shield and good array-shield thermal contact.	Yes	Yes	Good	None
2	To evaluate performance in the LBL configuration with no shield coolant flow.	Yes	No	Good	None
3	To evaluate performance without a shield.	Yes	No	Poor	None
4	To evaluate the performance of a local shield.	Yes	No	Poor	Side plane sides and to surrounded by local copper shield soldered to the coolant tube[1]
5	To evaluate the performance of side plane cooling by a spring contact thermal short.	Yes	No	Poor	Side plane side connect by copper short with spring contact to side and soldered to coolant tube[2]
6	To evaluate the performance of side plane cooling by a solder contact thermal short.	Yes	No	Poor	Side plane side connect by copper short soldere to both side and coolan tube[3]
7	To evaluate the performance of a total cooled shield and poor array-shield thermal contact.	Yes	Yes	Poor	None
8	To evaluate the cooling effect of the loop.	Yes	No	Poor	Simulated loop removed

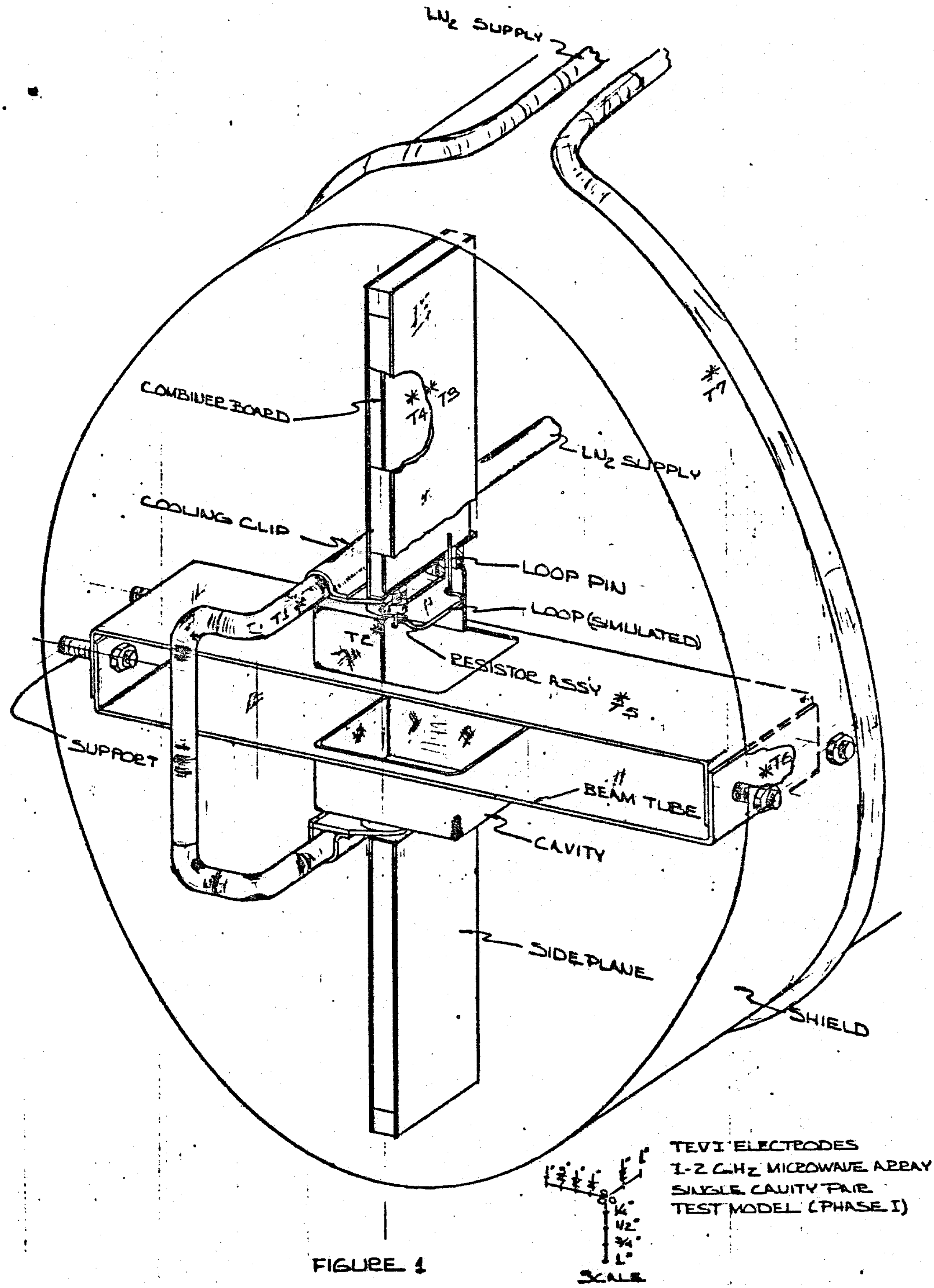
Notes
1 See Figure 3
2 See Figure 4a
3 See Figure 4b

TABLE 3
QUASI STEADY STATE TEMPERATURES

Run No.	Pressure [μHg]	Run Time [Hour]	TEMPERATURE [°F] T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8[1]
1	~ 0	7 1/2	-313	-295	-249	-273	-286	-295	-315	-
2	~ 0	10 3/4	-299	-188	-107	-164	-69	-38	-6	-
3	~ 0	9 1/2	-297	-201	-111	-169	-103	-87	15	-
4	~ 0	11 1/2	-302	-201	-137	-197	-102	-85	15	-300
5	~ 0	7	-300	-178	-90	-165	-78	-62	28	-
6	~ 0	8	-305	-222	-206	-263	-128	-109	20	-
7	~ 0	9 1/2	-315	-280	-234	-273	-241	-232	-314	-
8	~ 0	8	-302	-197	-104	-110	-95	-77	19	-

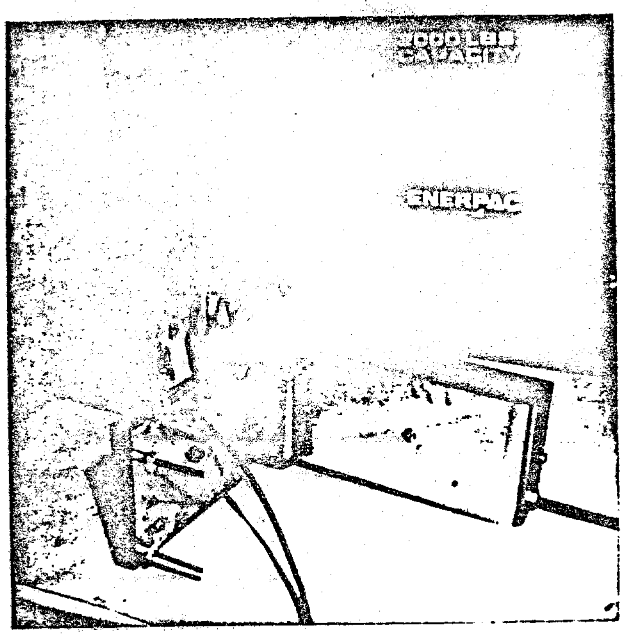
Note

1 Temperature on uncooled side of local shield

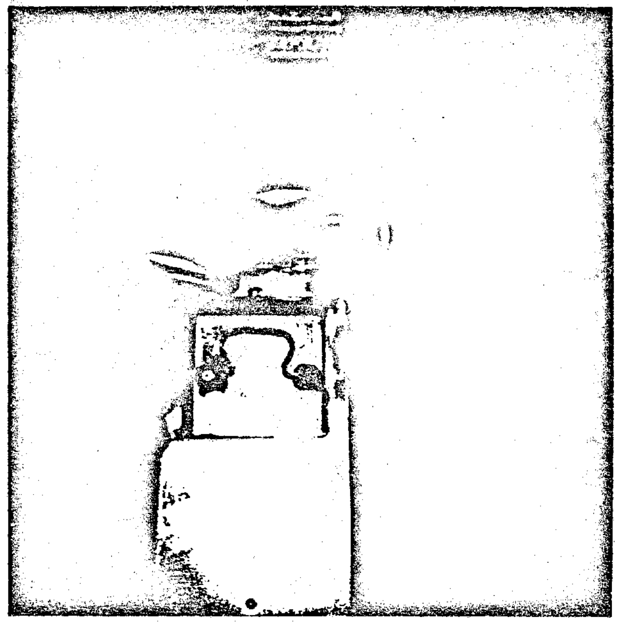


TEV I ELECTRODES
1-2 GHz MICROWAVE ARRAY
SINGLE CAVITY PAIR
TEST MODEL (PHASE I)

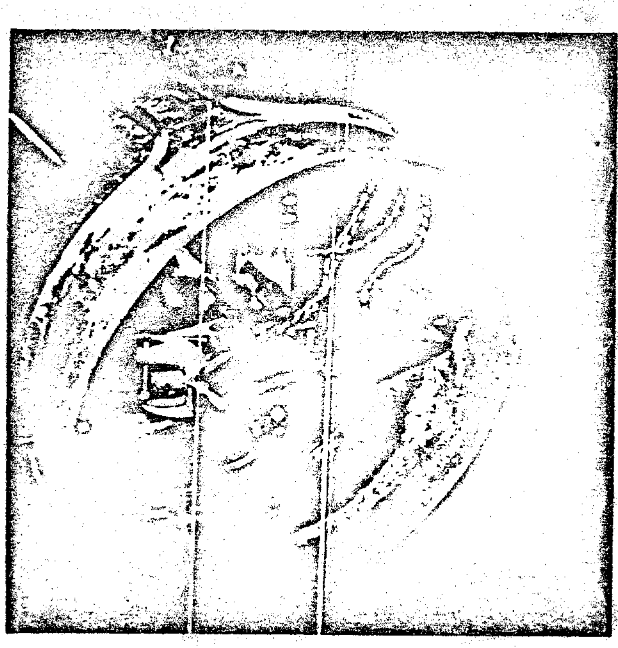
FIGURE 1



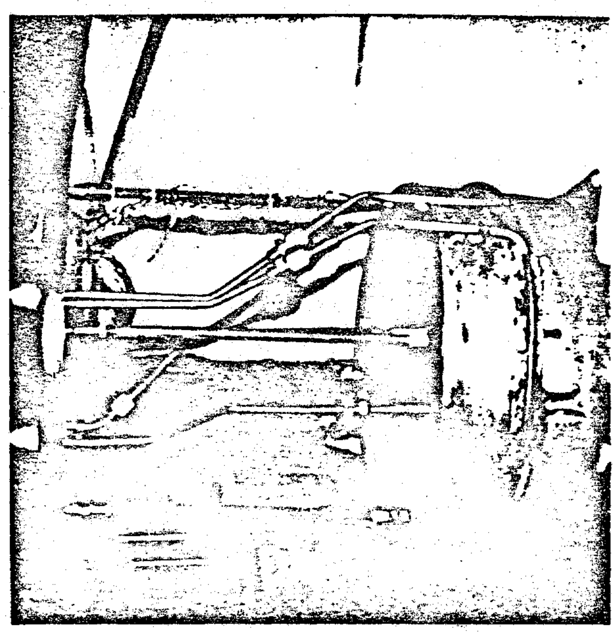
Test Article
Figure 2a



Simulated Loop
Figure 2b



Test Article-Shield
Figure 2c



Shield Mounting to Tank Flange
Figure 2d

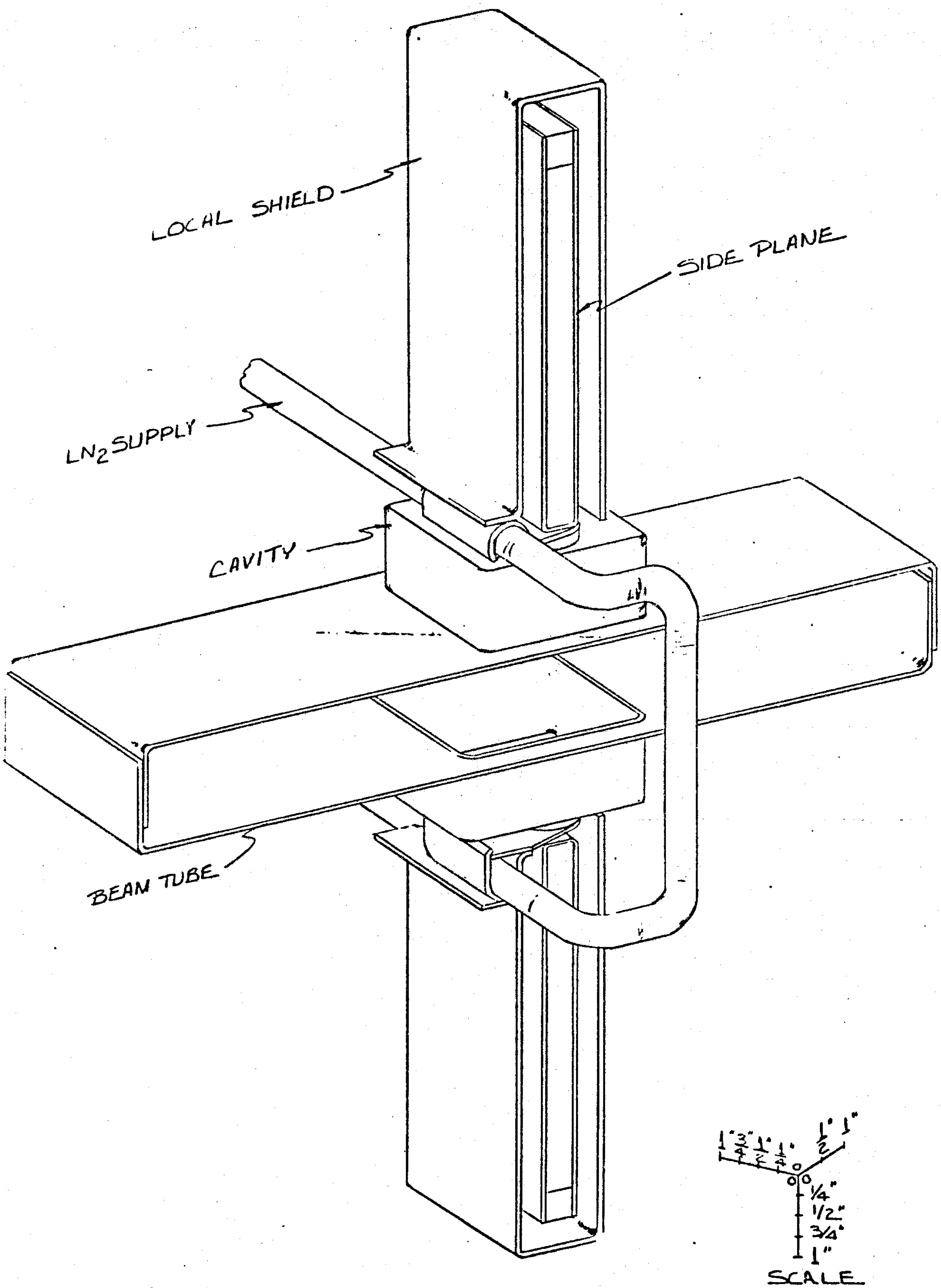


FIGURE 3

LOCAL SHIELD

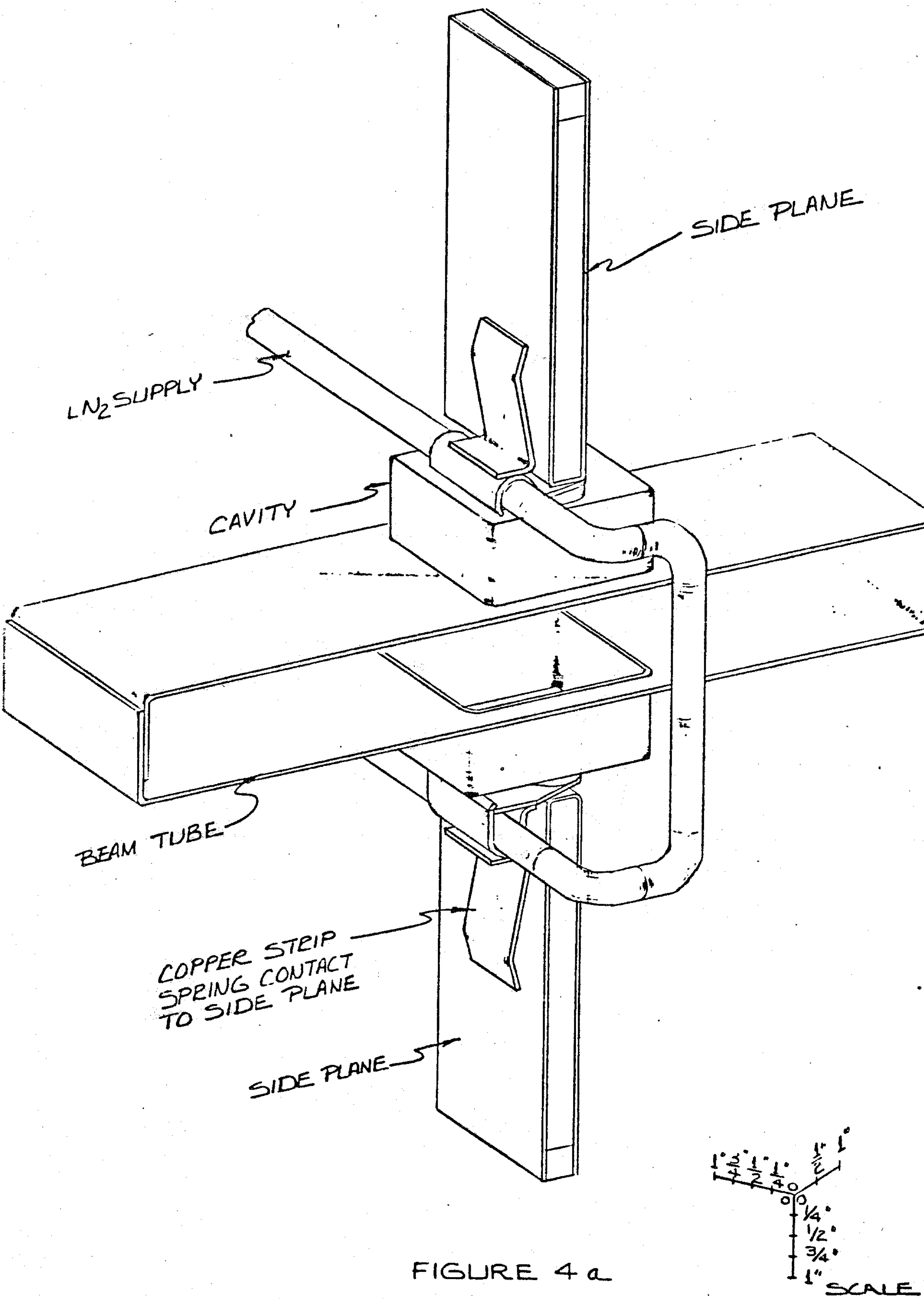


FIGURE 4 a

SPRING CONTACT THERMAL SHORT

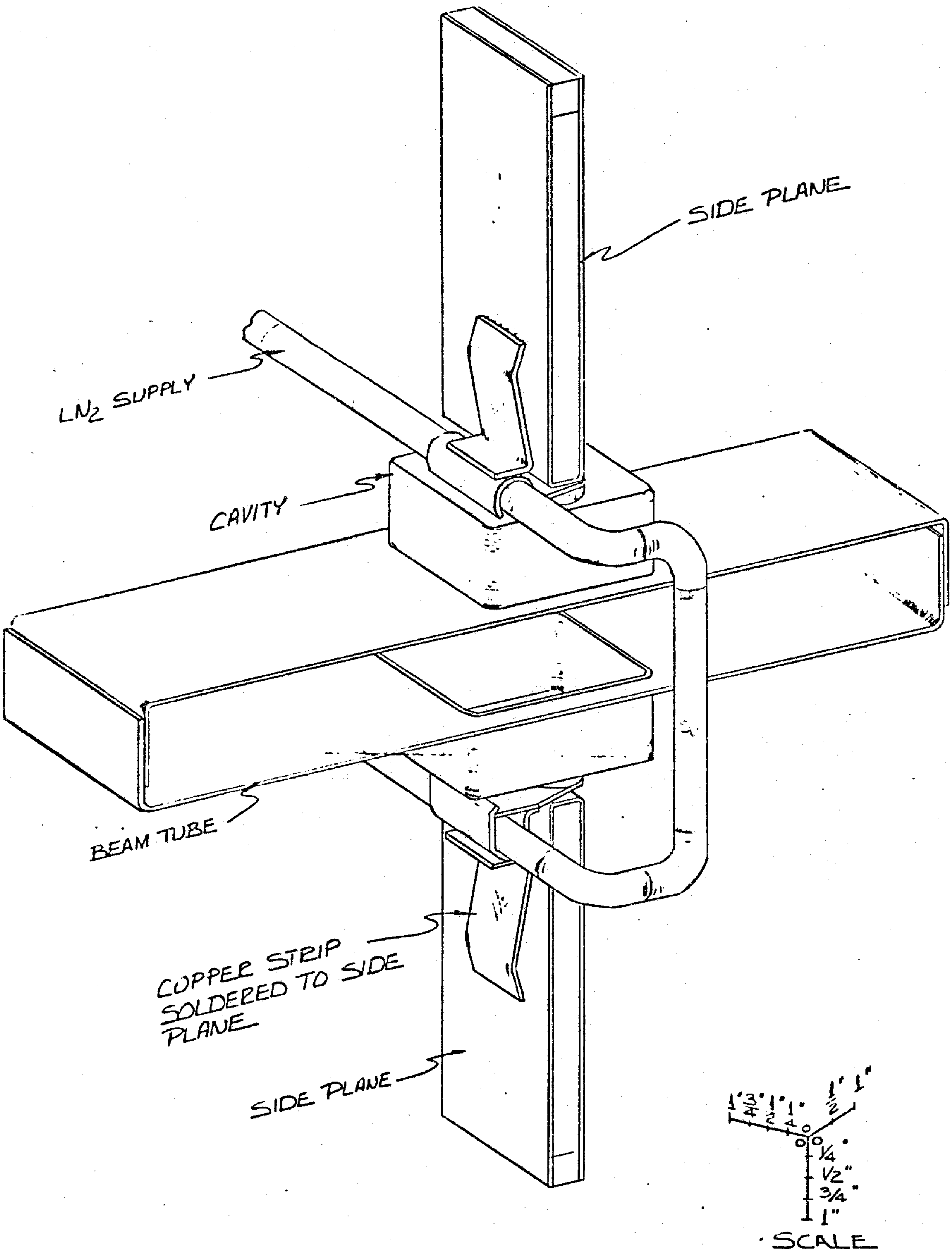
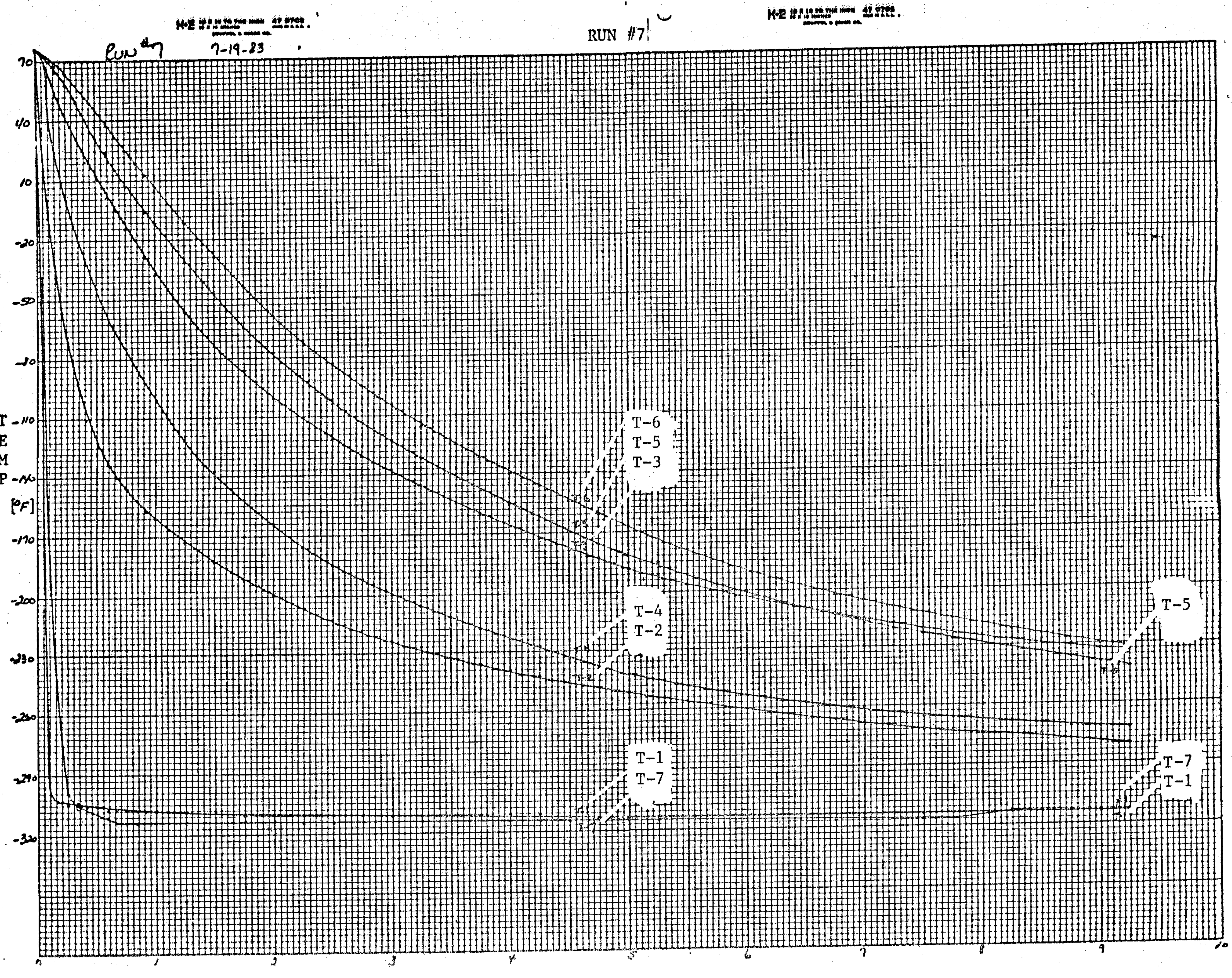


FIGURE 4b

SOLDERED CONTACT THERMAL SHORT



RUN #7
Run #7
7-19-83
T-6
T-5
T-3
T-4
T-2
T-1
T-7
T-5
T-7
T-1
TEMP [°F]
70
40
10
-20
-50
-80
-110
-140
-170
-200
-230
-260
-290
-320
0
1
2
3
4
5
6
7
8
9
10

MF/RN/DV
11/27/83

TEV I Electrodes
Formed Microwave Assembly
Single Pair Pickup Tests

I. Objective

The test objective was to continue the evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a pickup with liquid nitrogen cooling. Of specific interest was the determination of the steady state resistor temperature for an array located in a full, liquid nitrogen cooled shield.

II. Test Arrangement

The test arrangement as shown by Figure 1 is per the previous pickup cooling evaluation[1] with the following modifications:

A. An actual instrumented loop assembly was installed.
B. An etched combiner board was installed.
C. An instrumented combiner board connector was installed.
D. Good array-shield thermal contact was made with the use of brass, rather than G10, supports between the array and shield.
E. The shield end orientations were reversed; i.e., G10 at the interior with thermal isolation from the shield's cylindrical section.
F. Thermocouple were changed to Type T 28 gauge and were monitored with a commercial data logger having a built in reference junction. The thermocouple locations are as given by Table 1.

III. Procedure

The vacuum tank was evacuated to the minimum pressure obtainable with the pumping system.

Baseline temperature measurements were made with the test article at ambient temperature and with no coolant flow.

Liquid nitrogen coolant flow to the array and the shield was initiated.

Data was taken for a test period of twenty-four (24) hours.

V. Results

The transient cooling curves for the array LN_2 supply (T1), the array structure (T2, T5, T6), the shield (T7) and the resistor (T11) are as given by Figure 2.

1 "Single Pair LN_2 Tests", MF/RN/DV, 9/14/83

The array N_2 flowrate at discharge was 220 SCFH; i.e., equivalent to 13 liquid liters per hour. The shield N_2 flowrate at discharge began at 100 SCFH and was adjusted to 220 SCFH during the initial stage of the run.

V. Discussion

The resistor temperature is below that of the balance of the array structure due to its close thermal coupling to the LN_2 supply. The resistor operates at 15°F above the array LN_2 supply; i.e., -312°F, and 9°F above the shield; i.e., -306°F.

The array structure operates at an essentially uniform temperature; i.e., 10°F span, at steady state.

VI. Conclusion

Steady state resistor operating temperatures in the - 300°F; i.e., K, region should be obtainable where the resistor temperature runs approximately 15°F; i.e., 9 K, above that of the array coolant.

TABLE 1
THERMOCOUPLE LOCATIONS

TC No.	LOCATION
T1	$LNLN_2$ Supply Tube
T2	Cavity wall near resistor assembly
T3	Side plane at geometric center
T4	Circuit board on conductor at geometric center
T5	Beam tube at halfway point between cavity edge and beam tube edge
T6	Beam tube side at horizontal centerline
T7	Cylindrical shield
T8	Circuit board connector blade at point of attachment to circuit board
T9	Circuit board loop post at upper end
T10	Loop plate at geometric center
T11	Resistor loop post at upper end

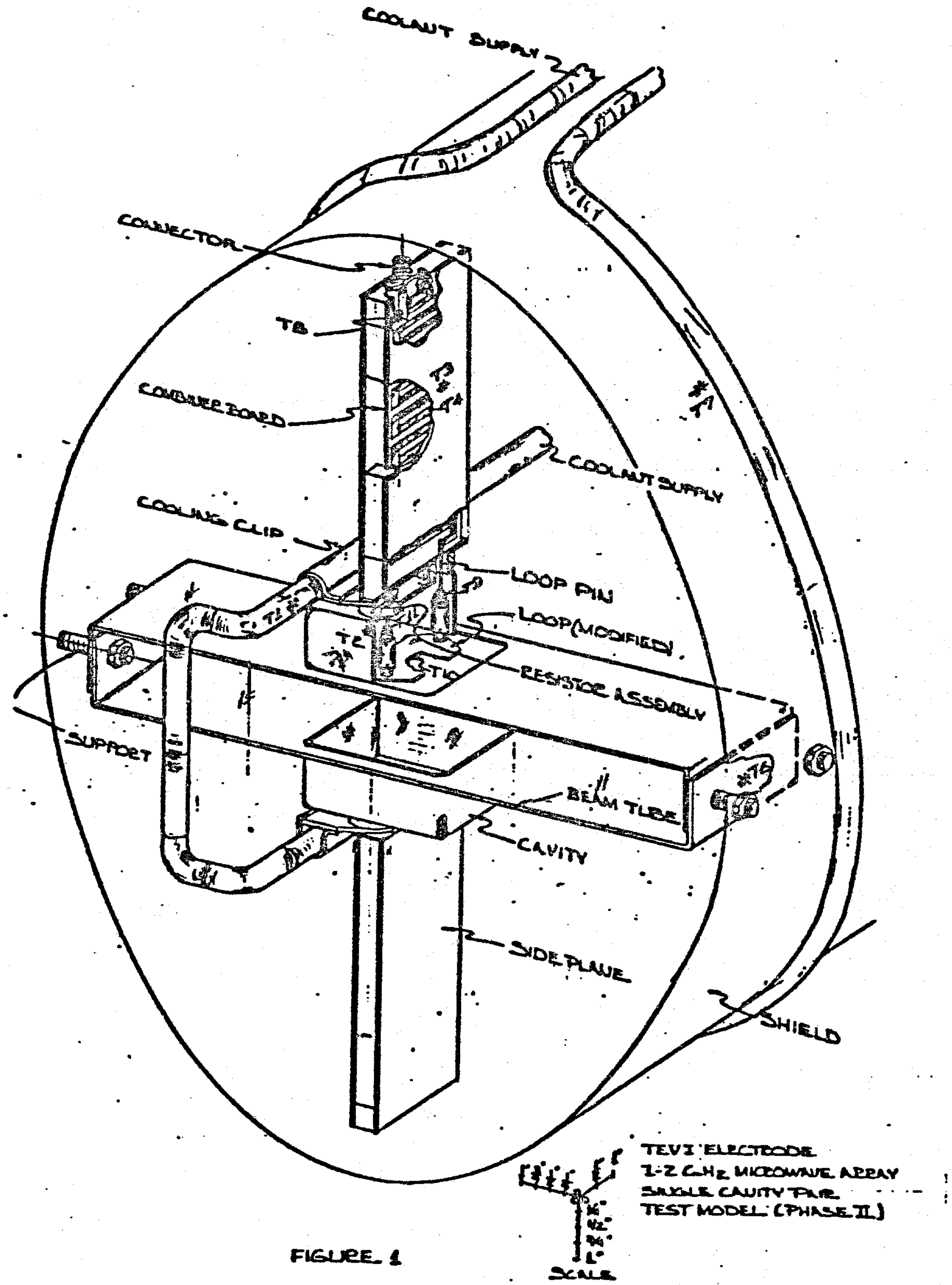
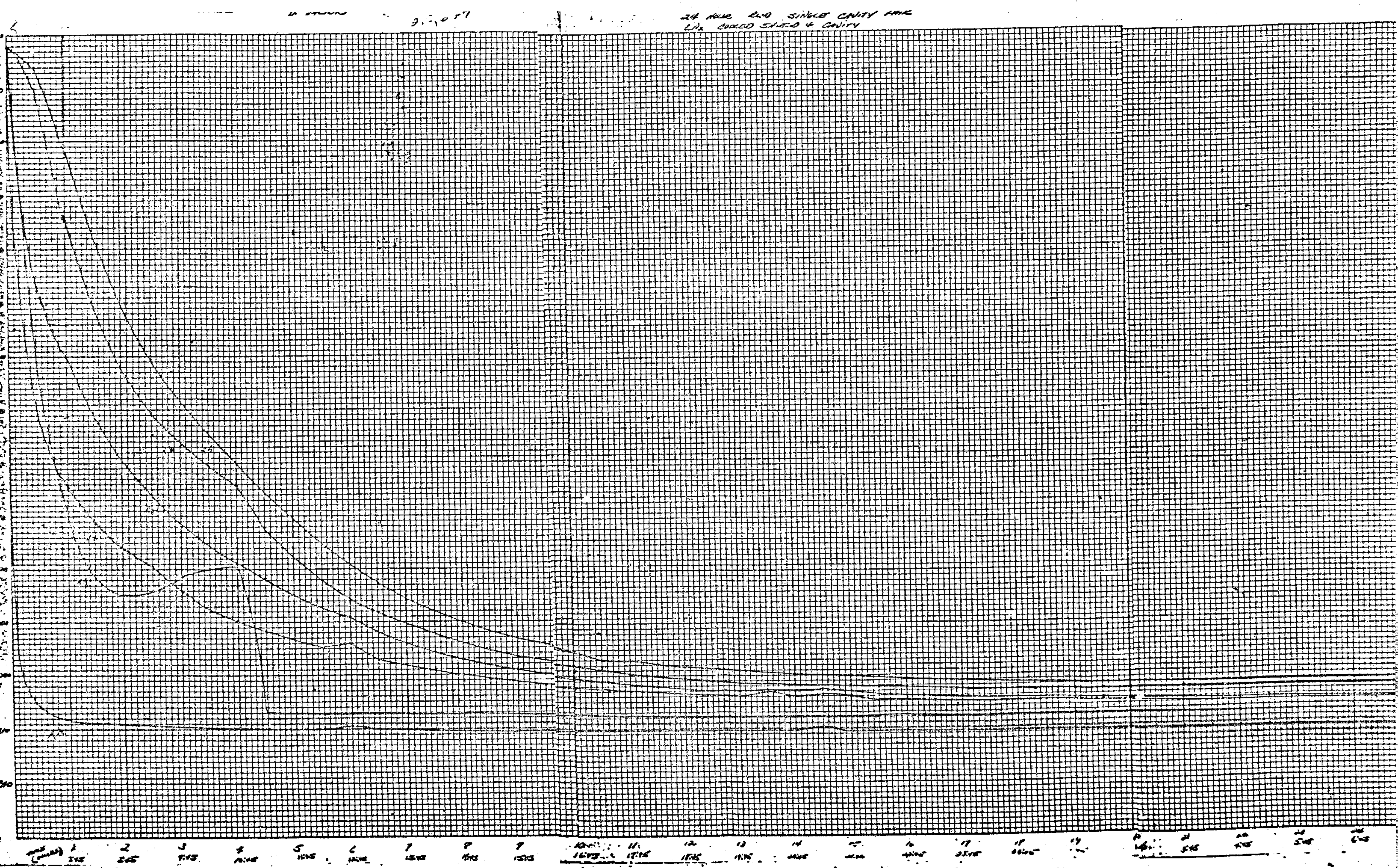

COOLANT SUPPLY
CONNECTOR
T8
COMBINER BOARD
COOLANT SUPPLY
COOLING CLIP
LOOP PIN
LOOP (MODIFIED)
RESISTOR ASSEMBLY
SUPPORT
BEAM TUBE
CAVITY
SIDE PLANE
SHIELD
TEV I ELECTRODE
1-2 GHz MICROWAVE ARRAY
SINGLE CAVITY PAIR
TEST MODEL (PHASE II)
SCALE

FIGURE 1


24 HOUR RUN SINGLE CAVITY HMC
LN2 COOLED SHIELD & CAVITY